

AN INVESTIGATION ON HEAVY OIL VISCOSITY THROUGH VISCOMETER AND NUMERICAL CORRECTIONS

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ABSTRACT

Heavy oil is a highly viscous crude oil which is difficult to recovery and contains a high amount of asphaltene and resins content. Excess of undesirable content in the crude oil increases the viscosity of crude oil. In this research article, heavy oil samples were collected in different oil fields and determined the viscosity. The viscosities of heavy oil samples were determined in the viscometer and the numerical corrections were examined for the fit in the heavy oil viscosity data. Applied dead oil viscosity correlations for the heavy oil samples widely diverged with the experimental values of redwood viscometer at 40 °C and 60 °C. In three of the four heavy oil samples showed an approximation in the viscosity value obtained by the experiment and correlation. Labedi was the only viscosity correlation that found to be near to the experimental value of redwood viscometer at 90 °C.

KEYWORDS: Asphaltene, Heavy oil, Labedi, Resin, Redwood Viscometer & Viscosity

Received: Jun 15, 2018; **Accepted:** Jul 05, 2018; **Published:** Jul 26, 2018; **Paper Id.:** IJMPERDAUG201873

INTRODUCTION

The depletion of light conventional crude oil led to the discovery of unconventional sources namely heavy oil, extra-heavy oil, bitumen and shale oil. Heavy crude oil is classified as unconventional crude oil due to troublesome recovery and production processes. °API categorize heavy oil from other crude oil in the range of 10°-22.3° (James G. Speight 1999). The reservoir viscosity of the heavy oil is between 1,000 to 10,000 cP. Heavy crude oil will always have a specific gravity below than water (Banerjee, Dwijen K 2012).

Heavy crude oil is a gas-free crude oil and high viscous due to the presence of high molecular weight compounds (Ahmed Hammami *et. al* 2007). The basic parameters such as °API, specific gravity, density, and viscosity are determined for the better recovery of heavy crude oil. The fundamental parameter will give the important properties of the heavy crude oil. The heavy crude oil viscosity is one of the key factors in the selection recovery method, mode of transportation and production sectors.

Heavy crude oil viscosity can be predicted using numerical correlations and also determined from the viscometers. The heavy oil viscosity correlations were given by many authors in various years. The viscosity correlations will be useful for the reserves estimation and prediction of Enhanced Oil Recovery efficiency (Bahadori A *et al* 2012). The correlation of heavy oil viscosity was improved by the authors in the collection of a large amount of data directly from different heavy oil fields.

Heavy oil viscosity correlations were predicted by many developers namely Beal (1946), Beggs and Robinson (1975), Glasø (1980), Labedi (1992), Egbogah and Ng (1990), Petrosky (1995), Kartoatmodjo and Schmidt (1990), De Ghetta (1994), Bennison and Elsharkawy (1999) (Bahadori A *et al* 2012, James G. Speight

1999).

Table 1: Range of Data Points, °API and Viscosity for Developers Correlations (Larry W. Lake 2007)

Developers	Range of		
	°API	Viscosity	Data points
Beal	10.1 – 52.5	0.865 - 1550	753
Beggs and Robinson	16.0 – 58.0	-	460
Glasø	20.1 – 48.1	0.616 – 39.10	29
Labedi	32.2 – 48.0	0.66 – 4.79	91
Egbogah and Ng	5.0 – 58.0	59 - 179	394
Petrosky	25.4 – 46.1	0.725 – 10.25	118
Kartoatmodjo and Schmidt	14.4 – 59.0	0.506 – 682.0	661
De Ghetta	6.0 – 56.8	0.46 – 1386.9	195
Bennison	11.1 – 19.7	6.4 – 8396	16
Elsharkawy	19.9 - 48	0.6 – 33.7	254

In this research article, heavy crude oil samples were collected from different heavy oil fields in India. Specific gravity and °API of heavy crude oil sample were determined by ASTM D1250 and IP-200 (John Wiley and Sons 1988). The viscosities of heavy oil samples were determined in the viscometer by IP-70 and the numerical correlations were applied to the heavy oil data's (Tarek Ahmed 2010). The deviation in actual and predicted value of viscosity will be helpful in analyzing the correlation improvement, the nature of heavy oil viscosity and finding the better numerical correlation that fits heavy oil fields.

MATERIALS REQUIRED

Heavy crude oil samples were collected from four different heavy oil fields. Hydrometer and Redwood viscometer were required for the determination of specific gravity and viscosity of collected heavy oil samples.

METHODOLOGY

The specific gravity of all four heavy crude oil samples was determined by hydrometer (John Wiley and Sons 1988). By using petroleum measurements table, specific gravity at 60°F was determined. °API of heavy oil samples was calculated from the formula given below (John Wiley and Sons 1988).

$$^{\circ}\text{API} = (141.5 / \text{Specific gravity at } 60^{\circ}\text{F}) - 131.5$$

Once °API of heavy oil sample was found out, the viscosity of heavy oil samples will be obtained from redwood viscometer. A 50 ml heavy oil sample was taken in the beaker and poured in the viscometer. Thermometers were inserted inside the water and oil to monitor the temperature. Time taken to collect 50 ml heavy oil from the bottom of viscometer was noted. The viscosity of heavy oil was calculated at different temperature namely 40 °C, 60 °C and 90 °C. Similarly, all four heavy crude oil viscosities were determined at three different temperatures.

The different numerical correlations of heavy oil viscosity were applied in all four crude oil samples. The various heavy oil viscosity correlations used in the research article were Beal, Beggs, and Robinson, Glasø, Labedi, Egbogah and Ng, Petrosky, Kartoatmodjo and Schmidt, De Ghetta, Bennison and Elsharkawy (Larry W. Lake 2007, Tarek Ahmed 2010).

RESULTS AND DISCUSSIONS

The API of heavy oil sample was calculated and found to be 12.5°, 15.6°, 19.5° and 21.3°. The dynamic viscosity of all four heavy crude oil at different temperature was tabulated with the obtained results from redwood viscometer and numerical correlations. Table 1 to 4 gives the viscosity data of individual heavy crude oil sample at three different temperatures. A graph was plotted with the dynamic viscosity on abscissa and viscometer and developers on ordinate with the values from the tabulations.

The °API of heavy crude oil will decrease with the increases in crude oil density. In general, the viscosity of crude oil decreases with the increases in temperature of the crude oil. For heavy crude oil, viscosity reduction is the major parameter for the better recovery and production processes.

Table 2 gives the comparative values of redwood viscometer and developers at different temperatures. Figure 1 shows a very wide difference in the measured and correlation values of heavy oil viscosity. All numerical correlations were disagreeing with the experimentally obtained value for the 12.5° API. Table 3 gives the values of viscosity at 15.6° API in different temperatures. Figure 2 shows that the experimental viscosity value of 15.6° API at 90 °C found to be roughly equal to the Labedi correlation value. The experimental value of viscosity at 40 °C and 60 °C were not equivalent to any of the numerical correlation values.

Table 2: Viscosity Data of Crude Oil at 12.5° API in three Different Temperatures

Viscometer and Developers	Dynamic Viscosity (cP)		
	40 °C	60 °C	90 °C
Redwood Viscometer	9775.40	5961.21	2982.03
Beal	1598.713	395.292	62.754
Beggs and Robinson	517.80	82.37	19.66
Glasø	835.44	339.46	126.35
Labedi	510.29	417.66	335.23
Egbogah and Ng	390.74	154.96	65.68
Petrosky	385.09	217.75	116.47
Kartoatmodjo and Schmidt	800.41	371.02	159.56
De Ghetta	455.04	142.88	50.99
Bennison	1559.23	324.20	57.84
Elsharkawy	819.35	236.14	77.70

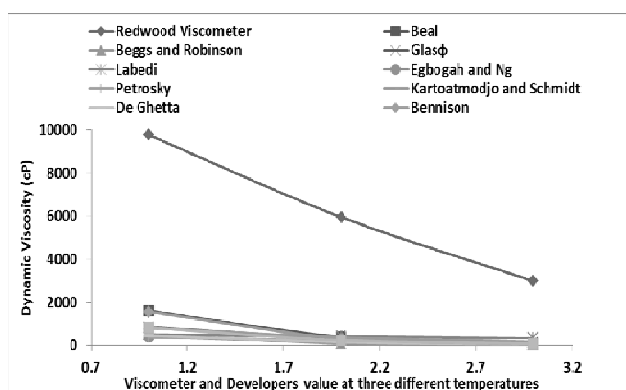


Figure 1: Viscosity Data of Crude Oil at 12.5° API in Three Different Temperatures

Table 3: Viscosity Data of Crude Oil at 15.6° API in three Different Temperatures

Dynamic viscosity (cP)	Dynamic Viscosity (cP)		
	40 °C	60 °C	90 °C
Redwood Viscometer	4982.75	2239.52	163.69
Beal	337.451	120.462	31.019
Beggs and Robinson	222.36	45.03	12.74
Glasø	224.19	101.89	42.88
Labedi	180.89	147.39	118.31
Egbogah and Ng	146.23	67.23	32.49
Petrosky	123.13	73.18	41.35
Kartoatmodjo and Schmidt	219.83	108.46	49.96
De Ghetta	217.27	78.25	31.36
Bennison	471.42	130.98	32.12
Elsharkawy	270.64	95.16	37.37

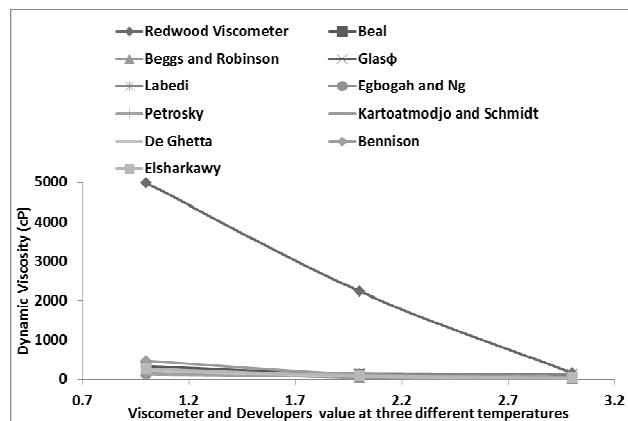


Figure 2: Viscosity Data of Crude Oil at 15.6° API in three Different Temperatures

Table 4 and 5 provide the viscosity data of heavy oil at 19.6° and 21.3° API in three different temperatures. Figure 3 and 4 indicates that the viscosity data obtained from the experimental value is approximate to the Labedi correlation value at 90 °C. The experimental value and numerical values of viscosity do not coincide in the other two temperatures.

Table 4: Viscosity Data of Crude Oil at 19.5° API in three Different Temperatures

Dynamic viscosity (cP)	Dynamic Viscosity (cP)		
	40 °C	60 °C	90 °C
Redwood Viscometer	2796.30	178.17	54.27
Beal	88.161	39.395	13.636
Beggs and Robinson	89.99	23.38	7.89
Glasø	66.07	33.32	15.72
Labedi	63.08	51.63	41.44
Egbogah and Ng	52.83	28.11	15.52
Petrosky	42.69	26.58	15.80
Kartoatmodjo and Schmidt	66.19	34.61	16.99
De Ghetta	97.17	40.39	18.32
Bennison	104.67	41.88	15.33
Elsharkawy	85.89	37.11	17.32

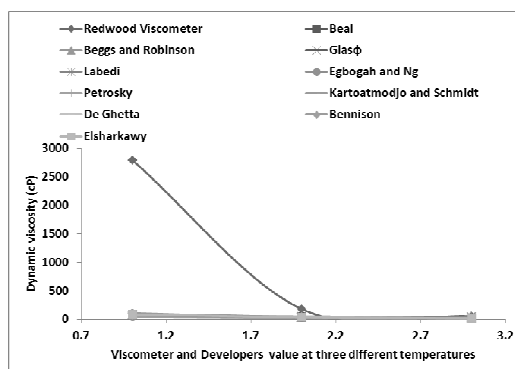


Figure 3: Viscosity Data of Crude Oil at 19.5° API in three Different Temperatures

Table 5: Viscosity Data of Crude Oil at 21.3° API in three Different Temperatures

Dynamic viscosity (cP)	Dynamic Viscosity (cP)		
	40 °C	60 °C	90 °C
Redwood Viscometer	1938.12	156.23	39.62
Beal	53.954	25.709	9.685
Beggs and Robinson	62.39	17.84	6.45
Glasø	41.78	21.91	10.78
Labedi	41.65	34.09	27.36
Egbogah and Ng	35.31	19.84	11.50
Petrosky	28.69	18.18	11.01
Kartoatmodjo and Schmidt	42.19	22.55	11.33
De Ghetta	69.63	30.69	14.63
Bennison	52.26	24.74	10.89
Elsharkawy	54.85	25.55	12.71

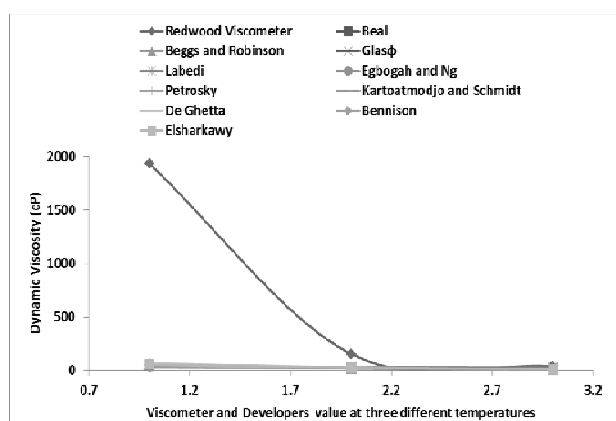


Figure 4: Viscosity Data of Crude Oil at 21.3° API in Three Different Temperatures

In all the numerical correlations, Labedi viscosity correlation was found to be close to experimental value at high temperature 90 °C for three heavy crude oil samples. Reduction in viscosity with an increase in temperature was shown clearly by the numerical correlations as well as experimental values.

CONCLUSIONS

Viscosity is the one of the primary consideration in any crude oil recovery method and production processes. In common, the viscosity of crude oil will decrease with the increases in temperature. The unconventional heavy oil have a

high viscosity, makes a tough decision in the selecting the suitable recovery methods. Viscosities of heavy crude oil samples determined by redwood viscometer were found to unfit with all the numerical correlations at 40 °C and 60 °C. Experimental viscosities of three heavy oil samples at 90 °C were near to the correlation data of Labedi. A labedi correlation was applicable for the high-temperature viscosity measurement of heavy crude oil in this case of research. The viscosity of heavy crude oil was highly affected by the rise in temperature, which was clearly observed in the redwood viscometer experimentation.

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